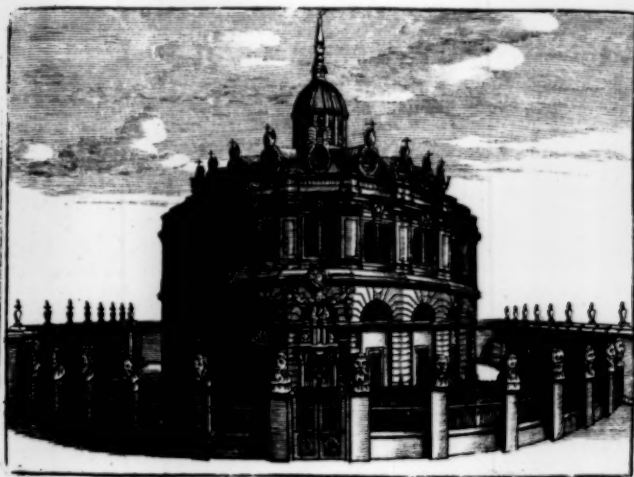


PROPOSITIONS  
*Concerning*  
OPTIC-GLASSES.

With their natural Reasons, drawn from  
Experiments.



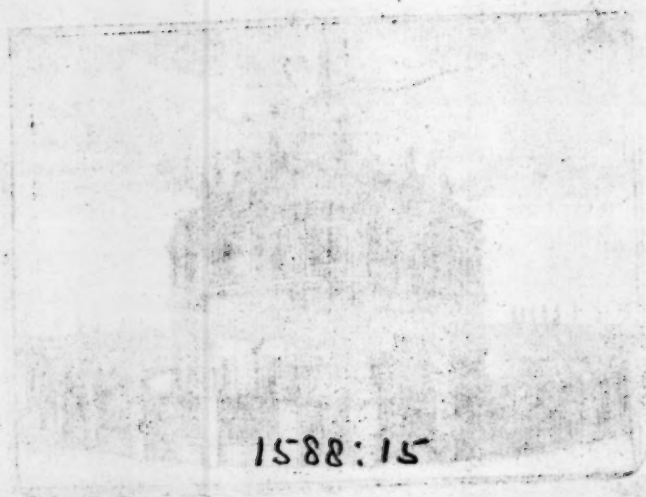
OXFORD,  
At the THEATER.  
ANN. DOM. M. DC. LXXIX.

PROPOSITIONS

Concerning

OPTIC-GLASSES

With their optical Properties, drawn out  
by Experiment



1588:15

OXFORD  
At the T H E A T R E  
AND HOW M L C I X I X

THE  
EXPLICATION

Of some terms.

**T**He union of the beams, both in perspective Convexes, and reflecting Concaves, not being at the center of such circle whereof the glass is a portion, but at the half-semidiameter, or thereabout; the Reader is desired that whensoever he finds any mention of the rays meeting in the center of the glass, he would understand the place of their union, and not the center of that circle whereof the glass is a part.

By the vertex of a glass, I mean the middle point of its superficies.

By conical rays, I mean those, which contract themselves, the farther they flow from the object, till they end in a point.

By

The explication of some terms.

*By circumferential, or circular rays, I mean those which dilate, or grow wider, the farther they flow.*

*By parallel rays, those which are always of the same wideness, neither dilating, nor contracting themselves, how far soever they are prolonged.*

PROPO-



# PROPOSITIONS

Concerning

## CONVEX GLASSES.

I. IF a grosser body pass thro a Medium more tenuous ( as a ball thro the air ) it divideth the Medium, and so suffers no division of parts; but if a more tenuous pierce thro a Medium more gross ( as the rays of light and colours passing thro misty air, water, or glass, ) it is divided by the Medium, and passeth disjoyned, if I may so say, thro the more porous parts of the Medium: and this division, and spreading of the beams (less or more) obstructed renders the appearance of the object sometimes bigger, sometimes nearer then it is.

II. Bigger then indeed it is: and hence also thro a thicker Medium it is seen out of its natural place; as a piece of Silver lay'd in the bottom of a pot empty, to one that stands at such a distance from it being not seen, if the pot be filled with water, the image there of at the same distance may be seen, from this thicker Medium aggrandizing and swelling the species, or beams, coming from the object, by not giving the rays thereof so direct a passage, but repelling, and reverberating some of them,



A

so

so that these advance forwards by many several oblique reflections, as in Fig. 1.

So also when the Beams of light pass thro a thick Glass, as we do see that some beams beaten back by the exterior solid parts of the glass enter not at all; so others, that enter in, do afterwards dash upon some inward parts of the same density, upon which when they fall obliquely, they are still so driven forwards, but somewhat turned aside, yet always by right lines; and so the whole body of them becomes more extended in breadth.

2. Nearer: the beams of the object as they are enlarged, and widened, so seeming shorter, as we see Cables swelled by Water in their thickness are accordingly shrunk in their length. So any thing lying in the bottom of a pot, or the bottom it self seems much nearer when the pot is filled with water than when empty. So part of a strait and equally thick rod being looked upon, part thro a thinner, part thro a grosser Medium (as part thro ayr and part thro water) that part seen thro the water seems both thicker and nearer to us then the other part doth; and hence it appears crooked and clubbed. So also Glasses magnifying the object, represent it nearer, as Convex glasses; diminishing, shew it farther off then it is, as Concaves.

2. The beams of an object falling directly upon the plain surface of a grosser transparent Medium, pass strait thro it, tho they may suffer some obstructions and oblique reverberations in their passage (as is said in the former proposition) and hence the perpendicular beam is said to have no refraction i. e. not to bend to one side more then to the other.

3. But the beams that fall obliquely that is (as some explain it) one part of the beam sooner, then another upon a surface plain, are said by them to receive a bend-

bending or declination; a declination that way where the shorter side of the ray happens to be; or where the ray first toucheth the thicker Medium; and so is stopped or hindred in his course; for that part of the beam which first comes to the grosser Medium now being supposed to move slower, and the other side not yet come to it to move swifter, this turns it about (as any thing doth that is in motion) when one side is suddenly hindred and the other still at liberty. Accordingly the declination or refraction of an oblique beam falling upon a plain surface of a grosser Medium, is supposed to be toward the perpendicular or middle ray drawn from the object to such a Medium. But contrarily when falling upon a plain surface of a thinner Medium, at its coming out of a thicker, such declination is supposed to be from the perpendicular. Hence some impute the vision of an Object that is in the bottom of a vessel filled with water (which object cannot be seen in the same station the vessel being empty) not to the swelling; but bending of the ray from the perpendicular at its exit out of the thicker (watry) into the thinner (aery) Medium; whereas a straight ray from the Object passeth above, and misseth the eye so placed, as in Fig. 2.

But quære farther concerning the truth of this third proposition since we find an oblique sun beam, passing in som part of its way thro glass, to fall on a wall, in the same point as if it had passed only



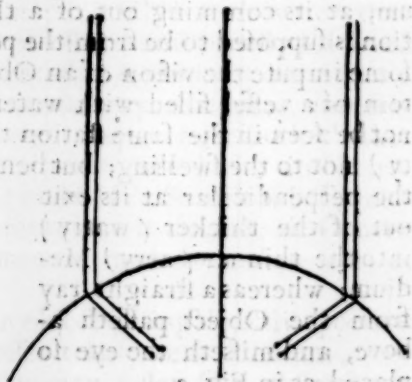
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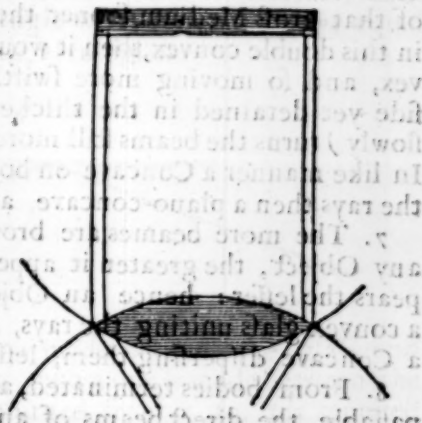
thro the air, in a strait line. Of which the reason perhaps may be, because it receives a contrary declination, when coming out of the glass, equal to the other declination, when coming into it, and so the beam becomes rectified.

4. The same it will be in the direct, and perpendicular beams of any object falling upon the oblique surface of a thicker Medium; which surface is either convex, or concave: if convex, the beams are refracted or bended towards the perpendicular, or middle ray (for always to that part of the ray which first toucheth the Medium, is the refraction made) as in Fig. 3.

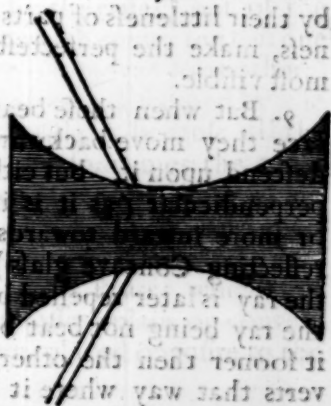
And the greater the obliquity the greater the refraction; for bending. Hence the beams passing thro a glass circular, and convex towards the object, are all brought towards the Center of the circle of which the glass is a portion, and many of them meet in it; those that fall more obliquely, and on the side of the glass, having a greater bending (because the one side of the ray in the more oblique is sooner stopped, and the other side mean while moves still forward a farther space at liberty, which turns the ray still more about) as in Fig. 4. those that fall less obliquely, a lesser.



You may observe also that the more any ray falleth on the side of the circle, it maketh the more acute angle, and the angle at its comming forth being equal to that at its entrance, and so also more acute, hence it hath a greater tending towards the center, then the ray that falleth neerer the vertex, so that the image of the Object if you take it upon paper placed at the Center of the glass, is there seen most exact and distinct, tho least or smallest.



5. But if the surface of the Medium be concave on which the beams fall, they are refracted from the perpendicular or middle ray, and so by passing thro such a Medium are much more disunited and dispersed.



6. Two convexes joined together, one towards the Object, the other towards the eye unite the beames much sooner (by a third part) then a Convex

toward the Object and a plain on the other side doth. Because the out side of the beam coming out of that gross Medium sooner then the inside thereof in this double convex, then it would do in a plano-convex, and so moving more swiftly ( whilst the other side yet detained in the thicker body moves more slowly ) turns the beams still more inward, as in Fig. 4. In like manner a Concave on both sides more spreads the rays then a plano-concave, as in Fig. 5.

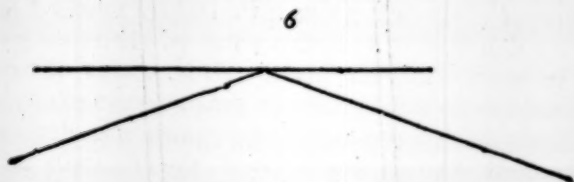
7. The more beames are brought to the eye from any Object, the greater it appears; the fewer, it appears the lesser: hence an Object looked upon thro a convex glass uniting the rays, appears bigger; thro a Concave dispersing them, lesser then it is.

8. From bodies terminated, and not penetrable or passable, the direct beams of an Object are reflected and beaten back in the lines of incidence, or the same way they came, if the surface on which the beams fall be smooth: otherwise a rough surface so breakes them, as they render no image at all of the object from whence they issue, and therefore those bodys which by their littleness of parts are capable of most smoothness, make the perfectest reflections, and the Object most visible.

9. But when these beams fall upon an oblique surface they move backward not in the same line they descend upon it, but either more outward from the perpendicular ( as it is in a reflecting Convex glass ) or more inward towards the perpendicular, ( as in a reflecting Concave glass ) as the outside or inside of the ray is later repelled by the oblique surface: for all the ray being not beat back at once, but one side of it sooner then the other, therefore in its return it diverts that way where it found later resistance, and that is toward the longer side of the ray, or that side which came later to the obstacle.

10. When

10. When a beam or line is reflected from a smooth surface of any body, whether plain or circular, concave or convex, the angle of reflection is always equal to that of its incidence, as in fig. 6.

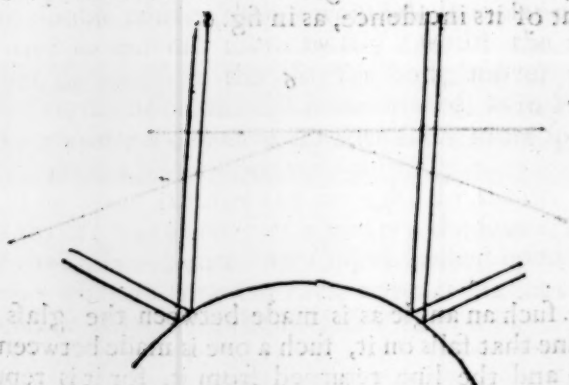


i. e. such an angle as is made between the glass and the line that falls on it, such a one is made between the Glass and the line returned from it, for it is repulsed equally, and wanting gravity there is no reason why it should decline to any side: but it is otherwise in heavy Bodies repulsed, which in their rebound are a little swayed downward by their weight (as in a Ball rebounding sideways:). The eye therefore as it is put in a several place, sees the Object by the reflex, not of the same, but a divers beam (that which comes to it in one place missing it when the eye is removed to another:). And hence the Object is not always discerned by the eye, when its Rays fall upon the Glass, because all the reflections may miss the eye, and sometimes the reflections which come to the eye, are only those which come from the cross Beams of the Object, and then the Object is seen inverted.

11. The reflections of the cross Beams which fall from an Object on reflecting Glasses, plain or convex, can never come to the eye when placed opposite to the Glass,

Because

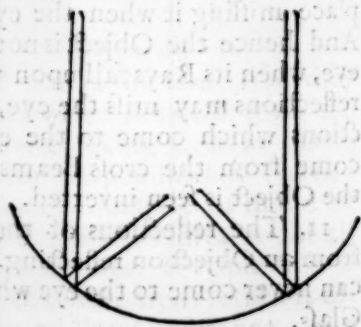




Because such beams spread much outward; as in fig. 7. nor yet which fall on a Concave reflective, or Convex perspective, when the Object is very near the Glass and within its Center. as in fig. 8.

Hence no Object can be seen revers (if it be directly opposite to the Glass) save from a reflective concave and a perspective convex, when the Object is placed without their Center, which two turne the Beams inward.

Also the Beams returned by a convex are



widened



widened and dilated; returned by a Concave, brought nearer and united. v. 4. 5. of Concaves,

12. So that now in reflexive vision, upon the reason forementioned, things are quite contrary to what they are in perspective vision. For an Object reflected from a Convex glass dispersing the rays, appears less, being seen only by some reflected lines which are nearer to the vertex of the Glass, the spreading of which also make every thing appear as if it were round, neither doth the image appear much behind the surface of the glass, never beyond the center thereof; but from a Concave uniting them, appears bigger then it is. Hence are Concaves in reflection, convexes in perspective used to aggrandize Objects.

All this which hath been said, may easily be understood, by putting a few bristles thro a peice of leather, or parchment, ( the holes in the parchment resembling the pores in the Glass, which are made streight by heat, and the bristles the rays ) and then bending the parchment concave, or convex-wise: where we may see how the ends of the bristles accordingly concur, or are farther severed. Of which spreading, or uniting of rays, by bended Glasses, Gassendus his expression ( amounting to the same effect with the other ) is this; that fire making the pores of Glasses all streight, so that in bending, or crooked Glasses, those happen not, as in plains, to be directly opposite to the Object; hence the beams coming from the Object upon such a Glass, are turned, and bended inward, or outward, and so are the more united, or dispersed, according as they dash against the hill, or side of the pore, and become also more or less bended, as they dash sooner upon such hill, ( as it is in beams more oblique; ) or later, ( as in those more direct. )

13. The same Ray falling upon an oblique surface,

or spreads over more space of it, then falling upon a plain, as in Fig. 9. & 10.

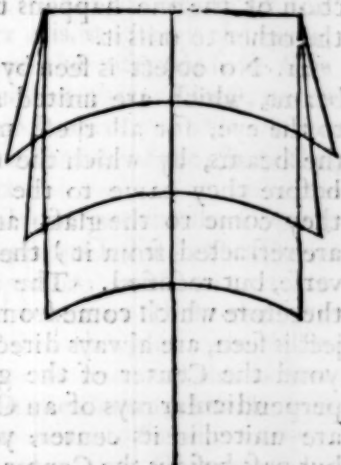
10. So that now in reflexive vision, upon the near and united. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27. 28. 29. 30. 31. 32. 33. 34. 35. 36. 37. 38. 39. 40. 41. 42. 43. 44. 45. 46. 47. 48. 49. 50. 51. 52. 53. 54. 55. 56. 57. 58. 59. 60. 61. 62. 63. 64. 65. 66. 67. 68. 69. 70. 71. 72. 73. 74. 75. 76. 77. 78. 79. 80. 81. 82. 83. 84. 85. 86. 87. 88. 89. 90. 91. 92. 93. 94. 95. 96. 97. 98. 99. 100. 101. 102. 103. 104. 105. 106. 107. 108. 109. 110. 111. 112. 113. 114. 115. 116. 117. 118. 119. 120. 121. 122. 123. 124. 125. 126. 127. 128. 129. 130. 131. 132. 133. 134. 135. 136. 137. 138. 139. 140. 141. 142. 143. 144. 145. 146. 147. 148. 149. 150. 151. 152. 153. 154. 155. 156. 157. 158. 159. 160. 161. 162. 163. 164. 165. 166. 167. 168. 169. 170. 171. 172. 173. 174. 175. 176. 177. 178. 179. 180. 181. 182. 183. 184. 185. 186. 187. 188. 189. 190. 191. 192. 193. 194. 195. 196. 197. 198. 199. 200. 201. 202. 203. 204. 205. 206. 207. 208. 209. 210. 211. 212. 213. 214. 215. 216. 217. 218. 219. 220. 221. 222. 223. 224. 225. 226. 227. 228. 229. 230. 231. 232. 233. 234. 235. 236. 237. 238. 239. 240. 241. 242. 243. 244. 245. 246. 247. 248. 249. 250. 251. 252. 253. 254. 255. 256. 257. 258. 259. 260. 261. 262. 263. 264. 265. 266. 267. 268. 269. 270. 271. 272. 273. 274. 275. 276. 277. 278. 279. 280. 281. 282. 283. 284. 285. 286. 287. 288. 289. 290. 291. 292. 293. 294. 295. 296. 297. 298. 299. 300. 301. 302. 303. 304. 305. 306. 307. 308. 309. 310. 311. 312. 313. 314. 315. 316. 317. 318. 319. 320. 321. 322. 323. 324. 325. 326. 327. 328. 329. 330. 331. 332. 333. 334. 335. 336. 337. 338. 339. 340. 341. 342. 343. 344. 345. 346. 347. 348. 349. 350. 351. 352. 353. 354. 355. 356. 357. 358. 359. 360. 361. 362. 363. 364. 365. 366. 367. 368. 369. 370. 371. 372. 373. 374. 375. 376. 377. 378. 379. 380. 381. 382. 383. 384. 385. 386. 387. 388. 389. 390. 391. 392. 393. 394. 395. 396. 397. 398. 399. 400. 401. 402. 403. 404. 405. 406. 407. 408. 409. 410. 411. 412. 413. 414. 415. 416. 417. 418. 419. 420. 421. 422. 423. 424. 425. 426. 427. 428. 429. 430. 431. 432. 433. 434. 435. 436. 437. 438. 439. 440. 441. 442. 443. 444. 445. 446. 447. 448. 449. 450. 451. 452. 453. 454. 455. 456. 457. 458. 459. 460. 461. 462. 463. 464. 465. 466. 467. 468. 469. 470. 471. 472. 473. 474. 475. 476. 477. 478. 479. 480. 481. 482. 483. 484. 485. 486. 487. 488. 489. 490. 491. 492. 493. 494. 495. 496. 497. 498. 499. 500. 501. 502. 503. 504. 505. 506. 507. 508. 509. 510. 511. 512. 513. 514. 515. 516. 517. 518. 519. 520. 521. 522. 523. 524. 525. 526. 527. 528. 529. 530. 531. 532. 533. 534. 535. 536. 537. 538. 539. 540. 541. 542. 543. 544. 545. 546. 547. 548. 549. 550. 551. 552. 553. 554. 555. 556. 557. 558. 559. 560. 561. 562. 563. 564. 565. 566. 567. 568. 569. 570. 571. 572. 573. 574. 575. 576. 577. 578. 579. 580. 581. 582. 583. 584. 585. 586. 587. 588. 589. 590. 591. 592. 593. 594. 595. 596. 597. 598. 599. 600. 601. 602. 603. 604. 605. 606. 607. 608. 609. 610. 611. 612. 613. 614. 615. 616. 617. 618. 619. 620. 621. 622. 623. 624. 625. 626. 627. 628. 629. 630. 631. 632. 633. 634. 635. 636. 637. 638. 639. 640. 641. 642. 643. 644. 645. 646. 647. 648. 649. 650. 651. 652. 653. 654. 655. 656. 657. 658. 659. 660. 661. 662. 663. 664. 665. 666. 667. 668. 669. 670. 671. 672. 673. 674. 675. 676. 677. 678. 679. 680. 681. 682. 683. 684. 685. 686. 687. 688. 689. 690. 691. 692. 693. 694. 695. 696. 697. 698. 699. 700. 701. 702. 703. 704. 705. 706. 707. 708. 709. 710. 711. 712. 713. 714. 715. 716. 717. 718. 719. 720. 721. 722. 723. 724. 725. 726. 727. 728. 729. 730. 731. 732. 733. 734. 735. 736. 737. 738. 739. 740. 741. 742. 743. 744. 745. 746. 747. 748. 749. 750. 751. 752. 753. 754. 755. 756. 757. 758. 759. 760. 761. 762. 763. 764. 765. 766. 767. 768. 769. 770. 771. 772. 773. 774. 775. 776. 777. 778. 779. 780. 781. 782. 783. 784. 785. 786. 787. 788. 789. 790. 791. 792. 793. 794. 795. 796. 797. 798. 799. 800. 801. 802. 803. 804. 805. 806. 807. 808. 809. 810. 811. 812. 813. 814. 815. 816. 817. 818. 819. 820. 821. 822. 823. 824. 825. 826. 827. 828. 829. 830. 831. 832. 833. 834. 835. 836. 837. 838. 839. 840. 841. 842. 843. 844. 845. 846. 847. 848. 849. 850. 851. 852. 853. 854. 855. 856. 857. 858. 859. 860. 861. 862. 863. 864. 865. 866. 867. 868. 869. 870. 871. 872. 873. 874. 875. 876. 877. 878. 879. 880. 881. 882. 883. 884. 885. 886. 887. 888. 889. 890. 891. 892. 893. 894. 895. 896. 897. 898. 899. 900. 901. 902. 903. 904. 905. 906. 907. 908. 909. 910. 911. 912. 913. 914. 915. 916. 917. 918. 919. 920. 921. 922. 923. 924. 925. 926. 927. 928. 929. 930. 931. 932. 933. 934. 935. 936. 937. 938. 939. 940. 941. 942. 943. 944. 945. 946. 947. 948. 949. 950. 951. 952. 953. 954. 955. 956. 957. 958. 959. 960. 961. 962. 963. 964. 965. 966. 967. 968. 969. 970. 971. 972. 973. 974. 975. 976. 977. 978. 979. 980. 981. 982. 983. 984. 985. 986. 987. 988. 989. 990. 991. 992. 993. 994. 995. 996. 997. 998. 999. 1000.

Hence less quantity, or extent of an Object can be received by a convex, then by a plain superficies, or line, which is of the same length with the convex; because the crooked line is not so far directly extended; as Fig. 11.

11. Hence the ray falling upon such circular Medium, is seen thro it as more extended; and therefore the Object appears magnified. And because fewer rays overspread the whole compass of the convex glass, then would a plain; hence the rays fall from an Object upon it, as lines from a center, tending to a circumference,

rence, still widening more and more the farther they goe. as in Fig. 12.

16. Hence the farther the glass is removed from the Object as long as it is placed within the center of the glass (by center of the glass, I mean not the middle of the glass, but the center of the Circle, of which the Convex glass is a portion; which being a double Convex must be understood also to have a double Center, one toward the object, another toward the eye) still a less quantity of the Object is perceived; because that which is perceived, is enlarged as it goes farther.



17. Hence also the greater the Convexity of the Glass is (as the lesser the Circle is of which it is a portion, the more convex it is) the more it magnifies the Object, but the less quantity, or extent of the Object it receives; and the neerer must the Object be placed for direct vision; because it must be placed within, or at its Center. Contrary: the less the Convexity of the glass is, the less it magnifies, &c.

18. In a Convex glass of a larger sphere, the beams are united later. And sooner in one of a narrower compass.

19. Beams in the point of Union appear livelyest and most perfect. See no 4 & 7.

20. All Objects fall at all times on the glass both by perpendicular or collateral & by cross rays. But vision

according as the eye is placed in a several distance, is made sometimes by the one, and then it is direct; sometimes by the other, and then it is reverse: as the refraction of the one happens to light on the sight, and of the other to miss it.

21. No object is seen by any refracted or reflected beams, which are united and cross before they come to the eye; for all these miss the eye; and besides, if the beams, by which the Object is seen, crossed twice before they came to the eye (namely once before they come to the glass, and a second time after they are refracted from it) the Object would seem not reverse, but rectified. The refracted or reflected beams therefore which come from the glass, by which the Object is seen, are always direct, tho the eye be placed beyond the Center of the glass, for tho (n. 4.) all the perpendicular rays of an Object passing thro a convex, are united in its center; yet the oblique rays are not, but pass besides the Center. By which rays the Object is seen else-where, tho faintly. You may see this by setting the flame of a candle in the center of a concave glass, which flame is cast forth from the glass in an united body to a great distance beyond the Center of the glass: in which Center did all those beams perfectly unite, and so cross one another at the same distance on one side of the Center, as the glass is on the other, the beams should spread and divide to the same circumference and latitude as they had in the glass, But experience shows that the compass of light at a great distance from the glass is much narrower then the glass. And that the beams suffer indeed some dilatation, the further they goe, but by gentle degrees, running almost paralel one to another. *quære* Whether a greater portion of a circle do not less unite, and longer continue the concurrence of the beams, then

then a lesser portion doth? and whether a greater convex doth not more, as well as sooner unite them, then a lesser convex, or that of a larger Circle v. Concaves. n. 4.

22. If the object be placed within the Center of the glass, the neerer to the Center it is, it spreads the more, and the bigger it appears; but the vision of such Objects wherever the eye be placed, is always direct, never reverse. Again place the Object where you will, if the eye be placed within the other Center of the glass, the vision likewise is always direct.

23. As the Object, when placed within the Center, the neerer it is to the glass, appears lesser, tho a greater quantity of it then appears; and neerer to the center, bigger; so the neerer that the eye (placed within the center) is to the glass, the lesser still the Object appears, because many of the beams which are brought together in the Center, miss the eye being placed before this their meeting, see fig. 12.

24. If the Object be placed in one Center of the glass, or neer it, and the eye in the other Center, then is the perfectest vision, and the Object biggest, and most distinct.

25. If the object be in the Center, and the eye placed any where beyond the center, then the beams appear confused to it: hence we cannot magnify an Object, placed within the Center, by many Convex glasses added one to another. In the same manner likewise it is, if when the Object is beyond the center, the eye be placed in, or neer the Center. v. 3. of Conc.

26. If the Object be without one center of the Glass, and the eye without the other center of it, then, and then only is the Object seen (by its cross rays) reverse; and the neerer the eye, or object are to the center, the bigger, and more confused the Object appears, the farther either of them are removed from it, the lesser and more distinct.

27. The

27. The reversion is perfect and distinct, when the glass is removed twice the distance of its center from the object. These things may be seen in drawing a glass that is much convex ( and hath its center neerer ) by degrees further from an object, ( as some great letters or the like ) keeping your eye still without the other center of it, where the convex glasses will represent the object unreversed, still bigger and bigger, till it is drawn so far off, that the object comes to be in the center. Then the beams begin to cross, and render all confused. After which confusion the glass being drawn still further off, the object appears again distinctly, but reversed, and also double, if the glass be removed perpendicularly, and vision be made with both eyes, which reverse figure is biggest at the first, and as the glass is further removed from the object lesser and lesser; retaining then the just magnitude of the object, when the glass is withdrawn the Diameter of its circle, or the distance of two of its centers from it.

28. Whereas (n. 25.) if the eye be placed in the center of the glass, and the object beyond it, there is only confusion, the object then beginning to be inverted, a second convex glass being added to the first, and removed from it, the distance of the center of that glass, and besides this, the distance of its own center ( at which distance all the glasses in the longer perspectives are placed, so that the beams in the point where they are united by the first glass, are put exactly in the center of the second glass ) renders the object ( the reversion being now compleated ) clearly visible, and still reverse; whether you place your eye in, or beyond the center thereof; and much bigger then the first glass alone, having the same operation upon the beams, as they flow from, and are collected by the first glass, as the first glass is shewed before to have upon them as flowing from



from the object; so that the object is now twice magnified, and so it may be still more, by more glasses, placed in the same manner in respect of one another, where the object affords light enough: and these two glasses magnify the object the more, as they are made more convex, and portions of lesser circles.

29. A third glass being added in the same manner to the second glass, hath the same operation upon the image of the object, now presented to its center compleatly reverse, (which the object was not to the center of the second glass) as the first glass hath upon the object it self, and to an eye placed in the center of the third glass (or else place the eye beyond the center thereof, and it will shew it perfectly rectified) it shews all in confusion, as the first convex did: the object beginning now again to be turned the contrary way by it, to its proper figure, and to be rectified. Again a fourth convex, applyed in the same manner to the third, as the second was to the first, shews it perfectly and cleerly rectified, as the second doth shew it reverted. And this is the way of rectifying the object in the longer perspectives, where the object looked upon by one, or three glasses so placed, shews the object confused, by two or four, distinct and cleer. I say so placed, else one glass, placed at a further distance from another, will compleatly rectify the object, or the eye placed beyond the center, shall thro the glass discern the object, not confused, but inverted. Of the four glasses in the longer perspectives any two make a prospective reverse.

30. A second convex applied to the first, any neerer then the foresaid distance, renders the object less, then when placed in this point; and applied to it within the center of the first glass, represents it less then the first glass doth alone; and as it is put neerer, still the less;

fer; and the union of the beams is the sooner. (In a concave added the contrary happens) the reason is because then some few middle rays of the first glass fall upon the center of the second glass, the center of this being put within the point of their collection, and union.

31. Again, a second glass being removed any further from the first, renders the object bigger, but more confused, till it comes to confusion, and inversion.

32. As a Convex glass removed twice the distance of its center from the object presents it inverted, (see 27) so a second convex, removed from the center of the first glass (where the reversed object is presented unto it) twice the distance of its center, turns the object the contrary way, and rectifies it to an eye placed beyond the center of this glass, but to an eye placed in the center renders it confused. A third glass placed at the same distance from the second convex, will again reverse it.

33. The chief use of Convex glasses single, is for magnifying objects to the eye, which are placed within the center of the glass; the eye being also not without the center (for else after the object is reversed by the glass, afterward it is not augmented by such glasses, but much diminished.) In this manner are spectacles used, being convex-glasses some of a greater, some of a less circle. And when we would make the object (as suppose letters) bigger, we remove the glass further from it; the object as it comes nearer the center being more augmented; or we use a spectacle more convex.

34. But for the magnifying of objects, which are remote from us, and far beyond the center of convex glasses; which, if the eye be placed within the center of the glass appear very dim, and obscure, if the eye beyond the center, reversed and small; here a second glass is used, and that is



1. either a concave placed neerer, or a little before the center of the other glass, and the concurrence of the beams; which glass remedieth the confusion the eye finds there, and distinguisheth, and disjoineth the beams. And because the eye is applyed close to it, before the beams are much stragled, it also magnifyeth them and removeth the concurrence of them farther off, as may be seen by taking the image upon paper thro these two glasses in a darkened room. This is the composition of the short perspectives wherein the vision is direct. Or

2. Another convex glass removed from the first, the distance of the centers of both the glasses, (as is set down before n. 28.) This is the manner of the larger perspectives wherein the vision is reverse. By holding two convex glasses at this distance one from another, and putting our eye about the center of the nearest we may have a prospective without a Tube.

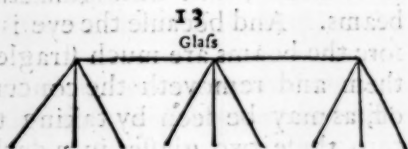
Quære concerning a short prospective composed of two convex glasses.

35. In these perspectives the first reverseth the object, and the second turneth it not again, not having so much distance from the first glass, as is shewed before; necessary to return it. But the second glass placed further off will first render it confused, then invert it.

36. The reverse appearance of the object (which happens when the object on the one side and the eye on the other are beyond the center of the glass) seems to be on this manner. The object when come to the center of the glass, falls upon it onely by som middle rays, or the rays coming from the very middle point of the object overspread all the glass (as is shewed before 16. n.) when all seems confused, because seeing onely one part, we see colour, but no figure of the body. But removed further it begins now to enter again on  
C the

edges of the glass, and to become visible only by some oblique and cross rays falling on either side of the glass and not by those falling on it before.

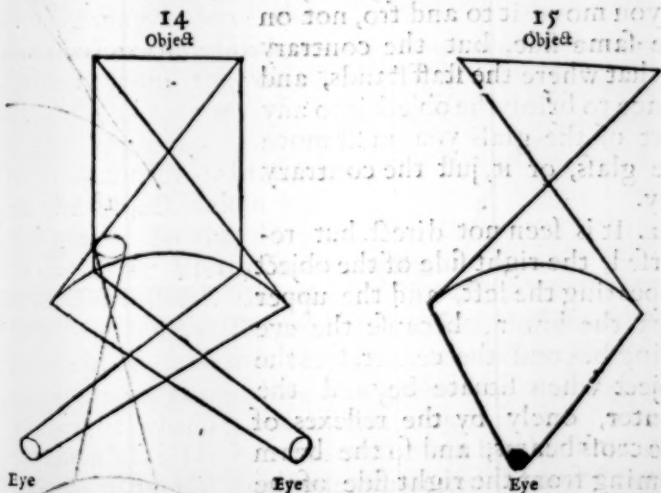
Not that the beams cross at some distance of it more than at another, for they streaming always every way



from every point of an object, so that the beams from any one point of the object fill the whole glass, and fill all the hemisphere continually, and therefore they must needs cross one another at all times: and hence it is that two looking in the same looking-glass do both see the object, but in a different place of the glass according to their several standing, as in fig. 13. Not that the direct beams, when the object is beyond the center, cease at all to fall on the glass, for the eye placed within the center, sees such an object by its direct rays, to which eye the object appears still erect and unreverse, but only that vision is sometimes by some rays, sometimes by others, as they are diversly received by the glass, and thence refracted to the point where the eye is placed (vid. conc. n. 4.) by reason of which 1. It is now seen not single, but double, as plainly appears if the glass be removed perpendicularly from the object, and we look with both the eyes upon it: when there will appear one image on one side of the glass, and an other on the other. Or, when covering halfe the glass yet one image will still appear. Indeed if we shut one eye we see but one image; but that image is onely on one side of the glass opposite to the eye we look with. As with the left eye we behold the image on the right side. Or, when looking with both the eyes we see but one image, and that in the middle  
of

of the glass; yet then the glass must be removed so much sideways first from the object, whereby we bring a side image into the middle of it. And this is the reason why to bring the object into the middle of the glass we move the glass from the object not toward it: as we move the glass to the left side, if we would bring the right side-image into the middle, and full view: because indeed so we come to have more full vision of the representation of the object, which is made on the right side or the edge of the glass. This appearance of the object doubled you may perceive if the object, and likewise the convex glass be not large. But whether it holds in greater convex glasses I am not certain, nor whether one image may not be som refraction of the other by reason of the oblique falling of the object on the glass by their cross rays.

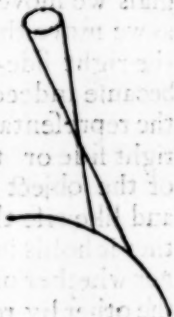
For the vision of the object appearing double and reverse, I suppose it made as in fig. 14.



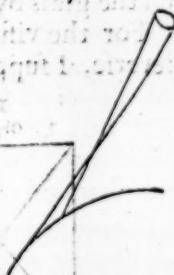
The vision of the object appearing single and reverse, as in fig. 15.

Note that the object by the cross rays, by which it is visible, falls always on the side of the glass that is opposite to the place where it is, as in fig. 16, 17, 18. (contrary to direct vision where the beams by which the object is seen, fall always on the same side of the glass.) And as in vision reverse every part of the object is shewed in a contrary position, so the whole object is shewed in as contrary a place of the glass; as if the object be on the right side of the glass, it appears on the left: as you may see by putting a staff, or any other thing between the object you hold in your hand and the glass. The image of which staff hinders the sight of the object, as you move it to and fro, not on the same side, but the contrary to that where the staff stands, and hence to bring the object into any part of the glass you must move the glass, or it, just the contrary way.

2. It is seen not direct, but reversed, the right side of the object appearing the left, and the upper part the lower, because the eye being beyond the center, sees the object when situate beyond the center, onely by the reflexes of the cross beams, and so the beam coming from the right side of the object, now is carried to the left



16



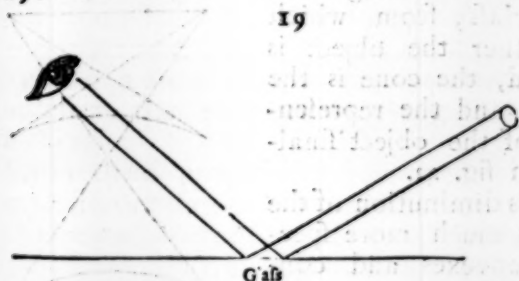
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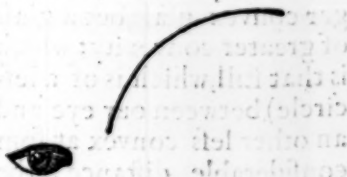
side

side of the eye, & e contra. Which thing we may also see in a plain lookin-glass placed obliquely in respect of the object and the eye, directly opposite to one another, where the image of the object shews reverse, as in fig. 19.



Now the same obliquity there is between the eye and the object, and the right or left side of a convex glass placed between them, as in fig. 20.

37. In this reverse vision we may observe that the further the glass is removed from the object the less is the reverse image thereof; and so more quantity or breadth of the object taken into the glass. So that such a glass now Epitomizeth and diminisheth the object (in comparison of simple vision) as much as it magnified it before reversion: we seeing the object now far bigger without the glass than with it. The reason of which is because the object is seen (when it or the glass is farther removed) not by the same cross rays as formerly. For those prolonged do now straggle, and pass besides the convex glass put at a greater distance;



stance; but by other cross rays, which are narrower, these as they are more extended in length, so contracting in breadth, as in fig. 21. where the eye and the object, which also is seen in the direct beams falling on a plain glass, from which the further the object is removed, the cone is the sharper, and the representation of the object smaller, as in fig. 22.

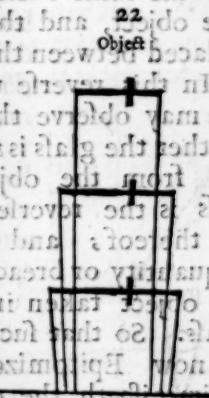
Tho this diminution of the object is much more speedy in convexes and concaves in the reverse vision.

38. And this lessening the object is more and sooner, the greater the convexity of the glass is. Therefore if we place a greater convex (by greater convex I always mean not a larger convex glass, but a glass of greater convexity, which is that still, which is of a less circle) between our eye and an other less convex at some considerable distance, the other will be shewed by this glass in the middle of it.

39. Again place the greater convex nearer the object and the lesser at its just distance (n. 28.) nearer the eye, this will shew more of the object, but less magnify it, then if they be placed the contrary way. The reason is because the object, by the greater convex



Object . 91 . 21



22

Object

Glass

set next it, is more diminished at the center thereof.

40. Hence also the less convexity the glass next the object hath, the object is by such glass the less diminished at the center thereof; and so ( the center of the second glass being placed at its center ) the bigger there this second glass finds the image of the object, and so the more magnifies it. Hence the more convex the first glass of a prospective is, the object thro it appears the lesser; the lesser convex the glass is the object's the bigger.

41. From these propositions concerning convex glasses magnifying the object by transmission of beams, may easily be gathered the reason of the magnifying by Concaves reflecting the beams, where the object appears direct, and much greater then it is, when placed neerer to the concave glass then its center, or then the semidiameter of the sphere, of which the glass is a section; but all confused when the object is removed to the semidiameter, and when the beams begin to cross; again, the object is seen onely on the sides of the glass, by cross lines and reverse, when the object is removed beyond the semidiameter, the eye also being placed beyond the center of the glass.

rays I say by them only visible for all both direct and cross beams fall from the object always upon the glass, whether the object be placed within or without the center thereof: ( see before n. 36. and fig. 15. ) onely imagine concave instead of convex. And this is the reason why if the flame of a candle be placed in the center of the glass, the light thereof is strongly darted out from the glass to a very great distance, ( whereas placed nearer or further of it gives a more faint reflection ) because the flame only ( so placed ) notwithstanding the whole glass, by which the glass sends forth nothing but these beams.



# CONCAVE GLASSES.

1. **A**S in a perspective Convex, so in a reflecting Concave the eye and the object being placed within the center of the glass; or secondly the object being placed within the center, tho the eye be without, or thirdly the eye within the center tho the object be without, the vision is never reverse but direct, because the reflections of the direct and not of the cross beams, come to the eye so placed.

2. As the object is removed farther from the glass till it comes to the center, it is seen still bigger, and as it grows bigger so a lesser portion of it appears, till at last the middle point of it fills the whole glass, which is when it cometh to the center, and then all appears confused; because colour onely is perceived, and not the figure and bounds of any body, of which we see onely one swelled particle: after which confusion, the object becomes visible again in all its parts by degrees, to the eye placed without the center, but onely by cross rays, I say by them onely visible, for els both direct, and cross beams fall from the object always upon the glass, whether the object be placed within or without the center thereof: (see before n. 36. and fig. 13.) onely imagine concave instead of convexes. And this is the reason why if the flame of a candle be placed in the center of the glass, the light thereof is strongly darted out from the glass to a very great distance, (whereas placed neerer or further of, it gives a more faint reflection) because the flame only (so placed) possesseth the whole glass; by which the glass sends forth nothing but these beams.



3. If the eye be placed in the center of the Glass when the object is beyond it, all appears confused, see the same in perspective Convexes (n. 25.) because more rays from all sides of the Concave come to the eye placed in the center, and so a small part of the object, fills all the Glass; for as an object is seen by more rays, every part thereof seems bigger, and so the glass receives fewer parts. And when thus a small part is seen, we discern the colour onely, but no figure or bounds of the body, and so all appears confused; so the neerer the eye is placed to the center, yet within it, it sees the object, placed beyond the center, the bigger, and the neerer to the surface of the glass. Likewise if the object be placed in the center of the glass, when the eye is beyond it, all appears confused to the eye, because one onely point of the object is swelled so big as to fill all the glass, which point, spread over all the Glass, the eye placed at whatever distance can onely see.

4. Both the object and the eye being placed beyond the center, as it is in perspective Convexes, (see before n. 26.) so in reflecting Concaves the reflections of the cross beams falling from the object, and not of the direct, can come to the eye. And so the object seen by these beams, is seen reverse or inverted, and in an opposite side of the Glass to that where the object is; whence, to bring it into any part of the Glass as you please, you must move it the contrary way.

The revers'd image appears largest at first, when neereſt the center, and less and less afterward. And you may observe also a doubling of it, if you take some little portion of the Concave, covering all the rest, and bring the object just into the middle. Some light colour'd and small body will shew you this most plainly, as a candle, a knife haft, &c. See all these be-

fore observed in perspective Convexes, n. 36, 37.

5. Now more cleerly to understand the reason why an object placed without the center of a reflex Concave, to an eye also placed without the center, is seen onely by croſs-lines, and ſo inverted, when the object ſo placed to an eye within the center is ſeen erect: you muſt remember what was ſaid before of Convexes n. 10, 11. From thence may be collected that the perpendicular, the ſpreading or oblique beams on the ſame ſide, the croſſing or oblique beams paſſing to the contrary ſide, are reflected in a Concave glaſs divers ways; ſom to, ſom beſides the center, ſom from the vertex of the Glaſs or inward (as I call it,) ſom from the vertex, or outward, and the ſame oblique beam alſo ſeveral ways, if the object be put in a ſeveral place. Hence as the object by ſeveral beams comes to the eye, ſo the object remaining in the ſame diſtance, and the eye being removed, it is ſeen erect, when the eye is neereſt the glaſs, then confuſed, then reverſe, as the eye goes farther off. Concerning the particular reflections of them, therefore note

1. That all the reflex beams of an object never meet, or unite at the center, or any other point of the Diameter, as is plain from this ground, that the angles of incidence and reflection are equal, which rule experience many ways confirmeth. And beſides, did all reflected beams meet in the center of the Glaſs, it would follow that no object could be ſeen by the eye, except when the eye is placed in the center.

2. That any two beams, whether parallel, ſpherical, or conical, falling from an object directly oppoſite to the Glaſs, upon it, at an equal diſtance from the vertex thereof, will meet always in ſom one point of the Diameter, either within or beyond the center, if the Diameter be prolonged to the place where they meet.

3. That

3. That all the perpendicular or parallel rays, which fall near the vertex of the Glas (which perhaps is the reason why Concaves are ordinarily made no larger then the sixth part of the circle, because a greater compass little or nothing advanceth the effect of burning) where-ever the object is placed, whether within or without the center, meet and cross one another near the same place of the diameter, namely about the half semidiameter, or half way to the center, as plainly appears in fig. 27. And the uniting of these beams there (which are by much the strongest, because the shortest) makes their pointing there so vigorous; and the uniting of them all, not in, but neer the same place, as likewise of som other beams Sphærical and Conical joyning with them causeth som latitude of the burning point.

4. That the oblique and spreading, or circumferential Rays of an object placed within the center, are reflected outward from the vertex of the Glas, as in fig. 31.

5. That the oblique beams of an object placed without the center, are reflected inward toward the vertex, as the parallels are; and som also of these, such as fall neer the vertex of the Glas, are united about the same place of the diameter with the parallel rays, and so augment the union, as in fig. 29.

6. That the cross beams, or the oblique-beams, which fall on the contrary side of the Glas, being much more oblique then those oblique ones which fall on the same side, are reflected, not inward or toward the vertex, as the other, but outward; hence these cross beams are the onely lines, that are reflected to the eye, when the object and it are both beyond the center, for whereas the other beams cross sooner, and so spread abroad and miss the eye placed without the

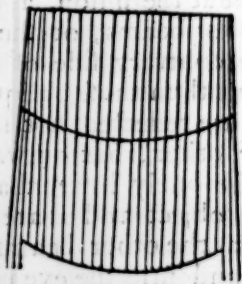
center, these onely without crossing one another, extend beyond the center, (see fig. 30.) And these crosse beams, if the object beyond the center be neer the glass, fall neer the vertex onely from the middle part thereof, and are reflected with a more obtuse angle, and so shew the object bigger to the eye, but a lesser portion thereof: but if the object be more remote, they are reflected with a more acute angle, and so shew the object lesser to the eye, but a greater portion thereof, as it happens also in plain vision.

7. That the object being placed beyond the center, the sphærical rays unite and crosse neereft to the center, the conical neereft to the vertex of the Glass, the parallel ones in the middle between these two, see fig. 27, 28, 29. 31. The object being placed within the center, the sphærical rays unite and crosse the further from the vertex of the Glass beyond the center and the object, and still farther beyond them, as the object is more approached to the Glass. See fig. 26.

8. That when any object is approached neer the Glass, many sphærical beams from the middle part of it, enter the glass, which when it is removed farther off, straddle on either side and miss the Glass, as in fig. 23.

23

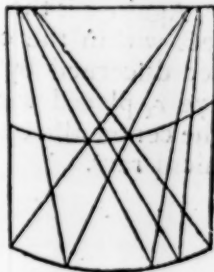
Object



Again

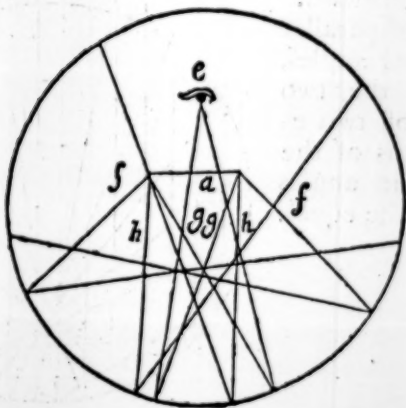
Again when the object is remote, many conical beams, from the extremities of it, enter the Glass, which the object being brought neerer, miss it. as in fig. 24.

24



In fig. 25. *a* is the object placed beyond the center, which is perceived at *e*, the eye, (placed beyond the center) onely by *g, g*, the cross lines, whose reflections tend towards the eye, when as the oblique rays *f, f*, that pass from it without crossing, falling upon the sides of the Concave, have their reflections inward between the vertex and the center; and the perpendicular rays *b, b*, as also the conical, that cross not before they touch the glass, have their reflection toward the center, and there cross one another. And therefore the object *a* is visible to the eye, *e* by none of these.

25



In fig. 26. *a* is the object placed within the center appearing not reverse, but direct, by the reflexes of the spreading lines *kk* to the eye *e*, placed without the center.

26

Again *a* is the object within the center discerned by the eye *e*, placed within the center also by conical rays.

27  
Object

Fig. 27. shews the reflection of parallel lines at equal angles, where, if the two lines cut off two equal sections of the circle, their angles must needs be equal.

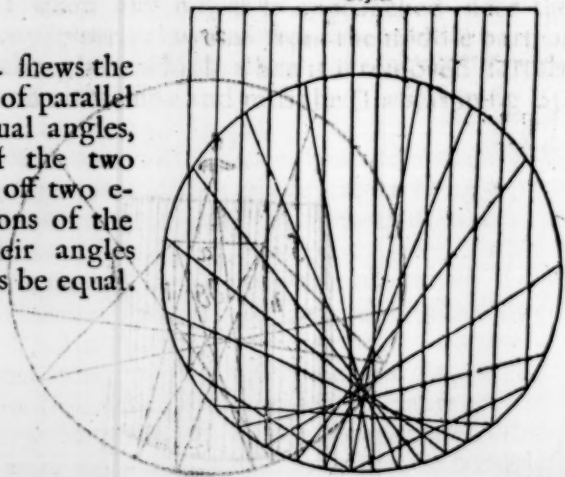


Fig.

Fig. 28. shews the reflection of Lines conical.

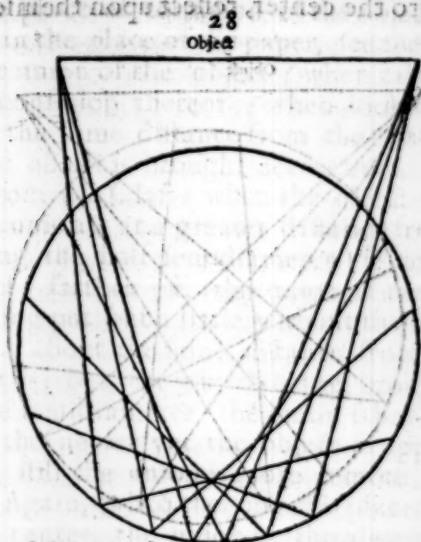


Fig. 29. shews the reflection of Lines spherical, the object being placed beyond the center.

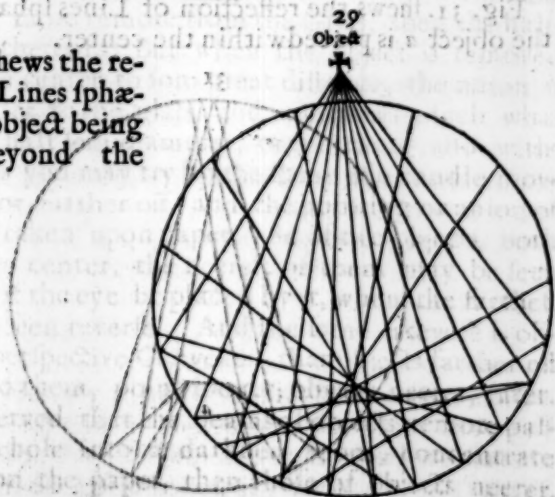


Fig.



Fig. 30. shews the reflection of cross Lines, those that pass thro the center, reflect upon themselves.

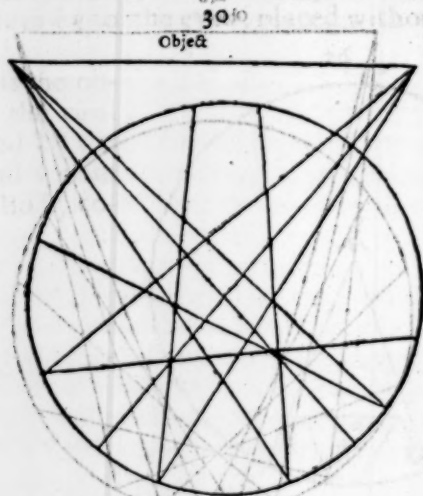
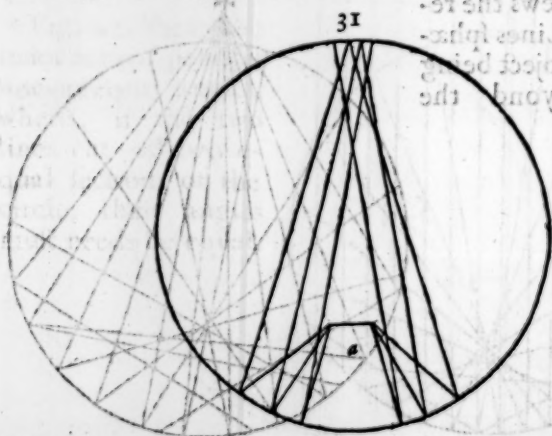


Fig. 31. shews the reflection of Lines spherical when the object *a* is placed within the center.





6. The point of union of the object taken upon paper is the place of confusion of the object, if you put your eye in the place of the paper, see the reason n. 2.

7. The union of the object (when taken upon paper) or confusion thereof (when look't on) is not always at the same distance from the Glas, but is varied as the object is brought neerer unto, or removed farther from the Glas: when the object is neerer the Glas, the union is at a greater distance from the Glas (exceeding the half semidiameter) i. e. contra, when the object's farther off, the union is neerer. So the object being put but a little without the center, the union of it is about the same distance from the Glas as the object is; but the object being brought to, or within the semidiameter, the union is beyond the center, and the neerer yet the object is approached to the Glas, still the union is more remote beyond the center. Again, when the object is placed not far beyond the center, the union is, tho' always within the center, yet more remote from the Glas, then the half-diameter thereof. But when the object is removed beyond the center to som great distance, the union is made neerer to the glas, and continues much what about the half semidiameter, or something also within it. This you may try by the flame of a candle moved neerer or farther off, and the pointing or union of its beams taken upon paper. So of two objects, both beyond the center, the neerest of them may be seen confused, if the eye be placed by it, when the farthest of them is seen reverse. And the same likewise is observed in perspective Convexes, that objects farther off passing thro' them, point sooner, objects neerer, later. So 'tis observed that the beams of objects remote passing thro' a hole into a darkned room, concentrate sooner upon the paper, then those of objects neerer.

Bejdo

E

The

The reason of this (as I conceive) is, because the union of objects afar off, is more by the conical rays, and so this union is neerer the vertex of the Glass; of objects neerer by the spherical rays; and so the union is more remote from the vertex, as may be seen fig. 28, 29.

8. As for refraction of beams, as they pass thro a perspective convex, I conceive that in all things it corresponds exactly to the reflections of them in Concaves; because I find in these punctually all the same conclusions and experiments, as in reflexe concaves; which would not be if the beams of objects were any otherwise disposed and modelled.

9. The perpendicular rays have no refraction (v. Conv. n. 2.)

10. The conical rays are refracted within, or neerer to the Glass then its center, some of them also being perpendicular to the convex, and so passing thro without any refraction, and by those is the object seen by the eye placed within the center.

11. The circumferential, as likewise the intercrossing beams, because they fall more collaterally and obliquely on the Glass, do not receive in their motion so much check and hinderance from it, as do the perpendicular ones, and therefore are refracted beyond the center of the Glass. The object placed within the center, being seen by the one, i. e. by the circumferential; placed without the center, by the other, i. e. by the cross beams.

12. Hence may be gathered the reason of the length, or protraction of the concurrence or union of the beams, which is observed in these burning Glasses; because there are many oblique beams, which from each side are reflected neer the center, which pass not just thro it.

13. The place of the appearance, or image of the object

object is very various, according to the figures of perspective glasses. A plain perspective glass shews the object in its due place, a Convex perspective renders the image of the object much neerer then indeed the object is. A Concave perspective much farther off. Again of reflecting Glasses, a plain one shews the image of the object as far behind the Glas, as the object it self is before, or short of it, the distance of the object being represented by its beams as well as its magnitude, and colours. And indeed were it as unusual a sight, it would be every whit as strange a one, to see on the surface of such a plain Glas (no farther passable by the species) the representation of an object as it were dived and retired a great way thro, and beyond it, as to see on the surface of a Concave the image thereof as it were approached much neerer to us. A reflecting Convex shews the image of the object within or behind, but always neerer then the center thereof. A reflecting Concave in direct vision, when the object is placed within the center of the Glas, shews the image thereof behind the Glas, and as the object is brought neerer to the center, and as it grows bigger, it shews it neerer to its surface; and when the object is in the center, it appears in the very surface of the Glas: removed yet farther beyond the center, the image appears before, and as it were coming forth of the Glas. For note, that as the reflected line which onely is seen by the eye, and not the line of incidence, is represented in direct visions much longer then it is, and so the object seems much beyond the Glas: so in cross vision, which is opposite in all things to direct, the object seems much neerer then the Glas; because the reflexe of the crossing beams appears much shorter then it is, and less removed from the eye, the crossing of the beams much dwarfing and shortning them to appearance. As any line of

the same length drawn streight forth, or perpendicular from the object seems to go farther from it, then an other drawn obliquely, as in fig.

32. *ab* is the direct ray, *ac* the oblique of the same length, which seems not to be so long. Again the nearer the object beyond the center is approached toward the center, the more is the image seen before the Glass: and the farther doth it come forth, and the bigger it is: so that the image may be advanced neerer to the eye, then the object it self is, if the object do not directly meet and so hide it, but be put a little on one side. But as any part of the object cometh to the center, so the answering part of the image becomes confused, and appears onely in the surface of the glass (according to n. 2. 3.)

20 And here note that a greater portion of a circle is required to render the image lively, and much advancing before the Glafs; els a little portion of a Concave, where the sides have no great latitude from the vertex, will shew the object reverse indeed, and duplicated; but not coming forth. So likewise the more you move the object to the vertex or middle of the glafs, the more the image advanceth before the Glafs, and is more lively and distinct; but move the object never so little side-ways, tho this declination be very inconsiderable in respect of the breadth of the Glafs, and the image is gon out of the Glafs, so moving the object side-ways, suppose three inches, puts the image out of a Glafs, which is ten inches broad; whereas the object, when not neer the center, and its image

image not so emergent, may be laterally moved much more space without its quitting the Glass.

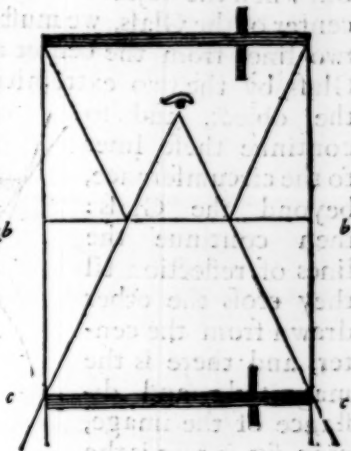
To know the place of the image in the several reflecting-glasses.

Here you must remember, that tho the object doth cast its rays upon all points of the Glass, yet it can be seen onely by that ray, which falls from such a point, from whence the angle which it makes with the Glass at its incidence, is equal to that which it makes with it when reflected to the eye.

33

1. In plains we must draw two perpendiculars by the sides of the object, and the Glass, and then continue the lines of reflection till they cross the perpendiculars, and there is the place of the image of the object, as in fig. 33.

*a* is the object, *b b* the Glass, *c c* the place of the image.



2. For Convexes we must draw two lines from the center of the Glass to the extremities of the Object, & then continue the lines of reflection, till these cross the lines from the center drawn to the extremities of the Object, and there is the place of the image as in fig. 34. *a* is the the Object, *b b* the Glass, *c* the place of the

the image, where the lines of reflection prolonged, cross the lines drawn from the center to the extremities of the object.

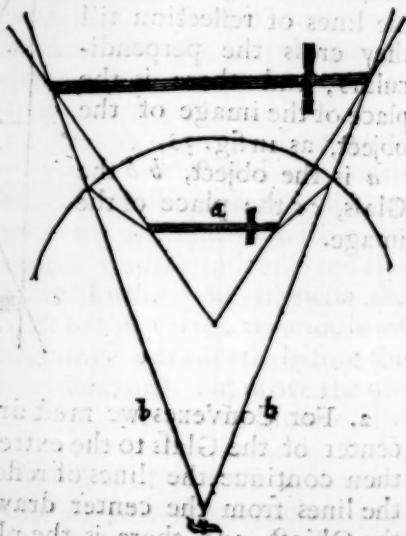
Where note, that the nearer this object is brought to the Glas; the wider will the lines drawn from the center, to its extremities, be; and the crossing of them by the lines of reflection sooner; and so the image bigger, and nearer the surface.

3. For Concaves in direct vision, when the object is within the center of the Glas, we must draw two lines from the center of the Glas, by the two extremities of the object, and so continue these lines to the circumference, beyond the Glas: then continue the lines of reflection till they cross the other drawn from the center, and there is the magnitude and distance of the image, as in fig. 35. *a* is the object, *b b* lines of reflection prolonged till they cut the central lines drawn by the extremity of the object, at which intersection the image is seen. Where observe also the

34



35



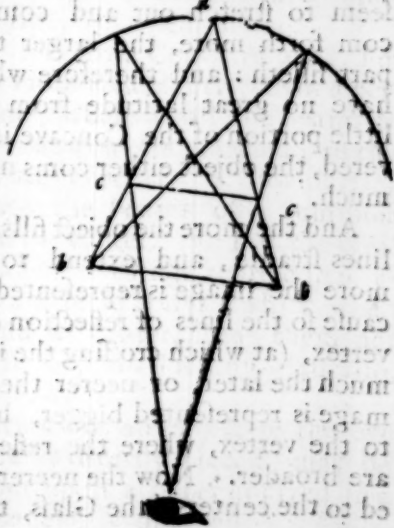
reason,



reason, why the object placed within the center, the neerer to the center it is, the image thereof appears the bigger, and the neerer to the surface of the Glass, because the central lines drawn by the sides of the object, are widened, as the object is brought neerer to the center: hence the image made between them is bigger, and the lines of reflection must sooner cross them, hence doth the image draw neerer to the surface of the Glass.

But in reverse vision, when the object is beyond the center of the Glass, and the image thereof appears not in the circumference beyond the Glass, corresponding to the center of the Glass, but between the eye and the vertex, as it were in a circle corresponding to it. To find the place of the image we must draw two lines from the vertex or middle of the Glass to the extremities of the object, and where the lines of reflection enter first within these two drawn to the vertex, there is the place of the image, as in fig. 36. *b. b.* is the object beyond the center of the Glass, *b. a.* lines drawn from the extremities of the object to the vertex of the Glass, *c. c.* the place of the image, where the lines of reflection cross those to the vertex.

Vision by cross lines whereby the object ap-



pears



pears reverse; is supposed to be as in fig: 37.

The reason of the appearance, and coming forth so much of the image before the Glas when the object is very neer the center, seems to be, because the neerer to the center the object is brought, the lesser parcel of it fills all the Glas, and so that parcel is rendred much bigger; now in this magnifying of it all its dimentions, the length as well as the breadth thereof, are enlarged; and the length being thus enlarged, it must needs seem to stretch out and com forth farther; and to com forth more, the larger the glas is, which such part filleth: and therefore when the sides of the glas have no great latitude from the vertex, as when a little portion of the Concave is used, and the rest covered, the object either coms not forth at all, or not so much.



And the more the object fills the Glas, and its cross lines straddle, and extend to the sides thereof, the more the image is represented before the Glas: because so the lines of reflection cross those drawn to the vertex, (at which crossing the image onely appears) so much the later, or neerer the eye: and so also the image is represented bigger, because the lines drawn to the vertex, where the reflecting lines cross them, are broader. Now the neerer the object is approached to the center of the Glas, the cross lines of the part

of the object seen, fall upon the two sides so much farther from the vertex, and hence the image cometh forth most, when the object is neereſt the center, and then also it cometh forth the farther, if we force the image more to ſom ſide of the Glaſs, by removing the object a little towards the other ſide, ſo that the image and object paſs beſides one another, when the eye may ſee both the upper and lower ſide of the object at once, one in the object it ſelf, and the other in the reverſed image thereof. This reflection alſo of the object when ſo neer the center, from the extremity of the Glaſs, is the reaſon, why at that time the left ſide-way motion of it puts it out of the Glaſs, as was noted before: yet the image, when thus coming forth, appears onely in the middle of the Glaſs; becauſe it appears onely where the reflected lines croſs the Vertical: and perhaps this is the cauſe alſo why the object, which is duplicated in a ſmall portion of the Concave, when it comes thus forth in a large, is joyned in one.

The cheiſeſt uſes of the reflecting Concaves are, 1. For burning, which it doth more vehemently, then a perſpective Convex: becauſe, where as all the beams do not paſs thro that, but that ſom are reflected; in this none paſs thro, but all are reflected. 2. For darting out to a great diſtance the beams of a luminous body, when placed in its center. 3. For the pleaſure of ſeeing the images of things represented upon it (eſpecially white and lucid bodys,) which when they are ſituated beyond its center, ſhews them not immerſed and behind it, as plain looking-glaſſes do, but in the ſurface of it.

Many of the apparitions of an object to the eye (looking thro Convex glaſſes diverſly placed) may be ſeen in a darkned room, upon a paper applied in a right diſtance to ſuch Glaſſes ſitly diſpoſed.

And here first note, that the Retina or bottom of the eye answereth to the paper, upon which the image appeareth, the Christalline humor to the Convex glass, thro which it passeth, and all the rest of the eye, (except the hole of the pupil) is as the darkned room. But yet observe, that whereas the image is figured reverse upon the Retina, ybt the eye, or person sees the object direct, and in its natural site. Because seeing is a kind of subtler feeling, or touching as it were the object at a distance by the straight staff of the ray coming from it. Therefore by the beam touching the upper part of the Retina, it toucheth or apprehendeth the lower part of the object, and e contra. As a blind man by his staff pointing downward gathers the thing touched to be below, which he would collect as well, were the staff made fast to the object, and he felt only the upper end thereof.

Hence also by the staff of the Optical axes from both eyes tending to the same punctual place, or from the same place tending to both the eyes, the sight perceives the object to be one and the same, but where many severall and disjoyned lines are made by any fault in some parts of the eye, or refraction in the medium, (as by passing the rays thro many severall holes, or thro a diaphanous body consisting of many severall plains and angles) here one single object to the same eye appears multiplicitious, and as being in many severall places where it is not.

Secondly note, that the Christalline humour, and the Retina in the eye answering to a Convex glass and the paper, the eye when using a Convex glass answers to two Convex glasses and the paper, and so the apparitions which happen to the eye, as it hath a severall application to one Convex glass, may be shewed also upon a paper in such a room thro two Convex glasses.

But thirdly note well, that if we go to compare the representation of the object, which thro a hole, or Convex glass, it makes upon the paper with that which the eye viewing it thro such a Glass receives, we shall find a main difference: because (as I said before) the eye and one Convex answers not to the paper and one, but two Convexes. For whereas upon the paper placed at the center of such a glass, the object appears most cleer and distinct, put the eye in the same place, and look thro the Glass upon it, and it appears confused. Again when upon the paper removed two centers off (after the crossing, and spreading abroad of the rays) all appears confused, or nothing but light instead of the object, to the eye placed there the object appears cleer, and distinct, onely reverse. Again that the object may appear reverse to the eye looking thro a Convex, the eye must be placed beyond the center of the Glass on one side, and the object also beyond the center of the Glass on the other side (see before of Convexes, n. 26.) and there are two interseptions of the rays by which the object is seen, one between the object and the glass, another between the glass and the eye, (see of Convexes, n. 36.) But the object is represented in a darkned room reverse upon the paper (whether there be a Convex glass, or no) onely by the crossing of the conical rays, not just at but a little within the hole, where they enter, between it and the paper.

Fourthly concerning the representations of Objects upon paper, thro som small hole in a darkned room, observe, that whether a Convex glass be used or no, the vision is much what after the same manner. The object is epitomized always, and rendred less then it is, and appeareth there more exact, distinct, and pleasant; by reason of the impediment of much

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light,

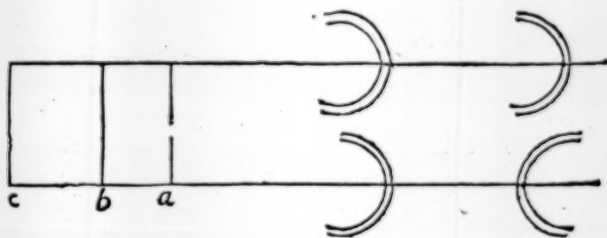
light, which darkens other weaker objects abroad, here removed; as perhaps, also by some coarctation, and conflux, and refraction of the beams in this narrow passage, more then in a free view of the object it self; onely if there be no Glas, the hole must be made so much the lesser (not exceeding the bigness of a little finger.) Likewise in respect of several objects, the paper must have a diverse application to see them more cleerly; for remote objects, it is to be placed neer the hole; for neer objects, farther off. See the reason hereof, n. 7. But first, a Convex glas placed at the hole by more uniting the rays, makes the object appear upon the paper placed at the center of the Glas, much more distinct, onely still reverse

Again a second Convex placed beyond the center of the first, where the rays are so spread that nothing but light, or a confusion of them, appears upon the paper: a second Convex, I say, there placed, recollects and reverts the rays, and makes the object to appear upon the paper placed at the center of this Glas, distinct and erected. And if another Convex be placed between this glas and the first, namely at the center of the first Glas, it will not prevent, or hinder altogether the crossing and spreading of the rays, but onely moderate it, and bring more of them, (kept from greater stragling) into the Glas, that is behind it: by which the object will appear more lively and cleer if three Glasses be used then if two onely. For the farther the image of any object is prolonged by Glasses, it (by reason of the stragling of many rays) will appear (ceteris paribus) more faint and dim.

A second Convex placed neer to the first within its center, shortens the concurrence or union of the beams, and lessens the object, and so shews the image distinct

distinct, and lesser upon the paper drawn neerer, contrary a Concave so applied, prolongeth the contour, and enlargeth the object, and so shews the image distinct, and greater upon the paper removed farther, as in fig. 37. A Convex glass placed before the

37



paper, whereon the object is seen, unites the beams, and makes the object most distinctly visible at *b*, another Convex being put before that Convex, at a fit distance, will unite the beams somewhat sooner, and make the object most distinctly visible at *a*; but a Concave being put in stead of this Convex, will render the union so much remoter, and will make the object most distinctly visible at *c*.

Hence also in the eye, when the Retina is too far from the Chrifalline humor, and beyond its center, or too neer it, and within its center, (at which center onely vision is perfect and distinct) or (which is the same) when the Chrifalline humor is too much, or too little convex in proportion to it, our sight is helped by the use of a Concave glass, where the Chrifalline is too convex, and by a Convex, where it is too flat. So also men, that see things, well neer hand, but dimly afar off, are helped with a Concave glass,  
others,



others, that discern things well afar off, (as some old men do) but dimly things neer, are helped with a Convex upon the same reason: so likewise the eye hath a power of varying its globosity, as the object being very neer, or very remote to the eye, hath need to have the center thereof abbreviated, or prolonged.



paper, whereon the object is seen, under the beams, and makes the object most distinctly visible at A, and the Convex being put in the same place, as a distance, will make the beams somewhat sooner, and make the object most distinctly visible at B, but a Concave being put in stead of this Convex, will render the object most distinctly visible at C, and will make the object most

distinctly visible at D. Hence also in the eye, when the Vision is too far from the Crystalline humor, and beyond its center, or too neer it, and within its center, (at which center only vision is perfect and distinct) or (which is the same) when the Crystalline humor is too much, or too little convex in proportion to it, our sight is helped by the use of a Concave glass, where the Crystalline is too convex, and by a Convex, where it is too flat. So also men, that see things well neerhand, but hardly afar off, are helped with a Concave glass, others



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DEPARTMENT OF THE INTERIOR

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